

## CLAIMS

I/We claim:

- [c1]            1.        A method for joining structures together, comprising:  
                 inserting a coupling device through a first aperture in a first structure and  
                 through a second aperture in a second structure;  
                 positioning the coupling device with a first section of the coupling device  
                 extending through the first aperture and a second section of the  
                 coupling device extending through the second aperture, but not into  
                 the first aperture; and  
                 applying at least one force to the coupling device to radially expand a  
                 portion of the second section of the coupling device extending  
                 through the second aperture toward an interior surface of the second  
                 aperture, while the first section of the coupling device in the first  
                 aperture remains at least approximately unexpanded in a radial  
                 direction.
- [c2]            2.        The method of claim 1 wherein inserting a coupling device includes  
                 inserting the coupling device through the first aperture having a minimum radial  
                 extent at least approximately the same as a minimum radial extent of the second  
                 aperture.
- [c3]            3.        The method of claim 1 wherein positioning a coupling device  
                 includes positioning a coupling device with the first section having at least one of a  
                 hardness, toughness, and density greater than that of the second section.
- [c4]            4.        The method of claim 1 wherein inserting a coupling device includes  
                 inserting a rivet.

- [c5]            5.        The method of claim 1, further comprising applying a first radial force to the interior surface of the second aperture with the radially expanded portion of the second section and applying either a second lesser radial force to an interior surface of the first aperture with the first section or not applying a radial force to the interior surface of the first aperture with the first section.
- [c6]            6.        The method of claim 1 wherein inserting a coupling device includes inserting a non-metallic coupling device.
- [c7]            7.        The method of claim 1 wherein inserting a coupling device includes inserting a coupling device through a first aperture in a first structure that includes a composite material and in a second aperture in a second structure that includes a metallic material.
- [c8]            8.        The method of claim 1 wherein inserting a coupling device includes inserting a coupling device through a first aperture in a first structure that includes a carbon fiber material and in a second aperture in a second structure that includes an aluminum material.
- [c9]            9.        The method of claim 1 wherein:  
                 the first section of the coupling device includes a head and a shank portion;  
                 and wherein  
                 the first aperture includes a countersunk portion for receiving the head; and  
                 wherein  
                 inserting the coupling device through the first and second apertures  
                 includes receiving the head in the countersunk portion.
- [c10]           10.       The method of claim 1 wherein inserting a coupling device includes inserting a coupling device having a first section that includes a head and a shank portion, and wherein a radial extent of the head is larger than a radial extent of at least a portion of the first aperture.

- [c11]            11.    The method of claim 1 wherein:  
inserting a coupling device includes inserting a coupling device having a  
                    second section that includes a shank portion and a tail, the tail  
                    extending out of the second aperture; and wherein  
applying at least one force includes applying at least one force that radially  
                    expands the tail of the second portion of the coupling device to have  
                    a radial extent larger than a radial extent of at least a portion of the  
                    second aperture.
- [c12]            12.    The method of claim 1 wherein:  
the first section of the coupling device includes a head and a shank portion,  
                    a radial extent of the head being larger than a radial extent of at least  
                    a portion of the first aperture; and wherein  
the second section of the coupling device includes a shank portion and a  
                    tail, the tail extending out of the second aperture; and wherein  
applying at least one force includes applying at least one force that radially  
                    expands the tail of the second portion of the coupling device to have  
                    a radial extent larger than a radial extent of at least a portion of the  
                    second aperture and clamps the first and second structures together.
- [c13]            13.    The method of claim 1 wherein inserting a coupling device includes  
inserting a coupling device having a sealant, and wherein the method further  
comprises dispersing the sealant.
- [c14]            14.    The method of claim 1, further comprising applying sealant in  
proximity to the coupling device.
- [c15]            15.    The method of claim 1, further comprising drilling at least one of the  
first and second apertures.

- [c16] 16. The method of claim 1, further comprising installing the coupling device, the first structure, and the second structure in a vehicle.
- [c17] 17. The method of claim 1, further comprising installing the coupling device, the first structure, and the second structure in an aircraft.
- [c18] 18. The method of claim 1 wherein applying at least one force includes applying at least one force in an acoustical upsetting process.
- [c19] 19. The method of claim 1 wherein applying at least one force includes applying at least one force with an electro-impact machine.
- [c20] 20. The method of claim 1 wherein applying the at least one force includes applying at least one force with an acoustical upsetting process and reflecting an acoustical wave to radially expand the portion of the second section of the coupling device.
- [c21] 21. A method for joining structures together, comprising:  
inserting a coupling device through a first aperture in a first structure and through a second aperture in a second structure,  
positioning the coupling device with a first section of the coupling device extending through the first aperture and a second section of the coupling device extending through the second aperture, but not into the first aperture, the first section having at least one of a hardness, toughness, and density greater than that of the second section; and  
applying at least one force to the coupling device to radially expand a portion of the second section of the coupling device extending through the second aperture toward an interior surface of the second aperture, while not radially expanding the first section of the coupling device or radially expanding the first section less than the second section.

- [c22]            22.    The method of claim 21 wherein inserting a coupling device includes inserting a coupling device through a first aperture having a minimum radial extent at least approximately the same as a minimum radial extent of the second aperture.
- [c23]            23.    The method of claim 21, further comprising applying a first radial force to the interior surface of the second aperture with the radially expanded portion of the second section and applying either a second lesser radial force to an interior surface of the first aperture with the first section or not applying a radial force to the interior surface of the first aperture with the first section.
- [c24]            24.    The method of claim 21 wherein applying at least one force includes radially expanding a portion of the first section toward an interior surface of the first aperture without contacting the first section with the interior surface of the first aperture.
- [c25]            25.    The method of claim 21 wherein inserting a coupling device includes inserting a coupling device through a first aperture in a first structure that includes a composite material and in a second aperture in a second structure that includes a metallic material.
- [c26]            26.    A method for making an aircraft, comprising:  
                 inserting a coupling device through a first aperture in a first structure and through a second aperture in a second structure, the first structure including a composite material and the second structure including a metallic material;  
                 positioning the coupling device with a first section of the coupling device extending through the first aperture and a second section of the coupling device extending through the second aperture, but not into the first aperture; and

applying at least one force to the coupling device to radially expand a portion of the second section of the coupling device extending through the second aperture toward an interior surface of the second aperture, while the first section of the coupling device in the first aperture remains at least approximately unexpanded in a radial direction.

[c27] 27. The method of claim 26 wherein inserting a coupling device includes inserting a coupling device through a first aperture having a minimum radial extent at least approximately the same as a minimum radial extent of a second aperture.

[c28] 28. The method of claim 26, further comprising applying a first radial force to the interior surface of the second aperture with the radially expanded portion of the second section and applying either a second lesser radial force to an interior surface of the first aperture with the first section or not applying a radial force to the interior surface of the first aperture with the first section.

[c29] 29. A system of joined structures, comprising:  
a first structure having a first aperture, the first aperture having a first interior surface and a first minimum radial extent;  
a second structure having a second aperture, the second aperture having a second interior surface and a second minimum radial extent at least approximately the same as the first minimum radial extent; and  
a coupling device having a first section extending through the first aperture and a second section extending through the second aperture, but not extending into the first aperture, the first section of the coupling device having at least one of a hardness, toughness, and density greater than that of the second section of the coupling device, and wherein a portion of the second section has a greater radial extent than the first section.

[c30]            30.    The system of claim 29 wherein the portion of the second section applies a first radial force to the second interior surface and the first section applies no radial force to the first interior surface or the first section applies a second radial force to the first interior surface, the second radial force being less than the first radial force.

[c31]            31.    The system of claim 29 wherein the first section is not in contact with the first interior surface.

[c32]            32.    The system of claim 29 wherein the coupling device includes a rivet.

[c33]            33.    The system of claim 29 wherein the coupling device includes a metallic material.

[c34]            34.    The system of claim 29 wherein the first structure includes a composite material and the second structure includes a metallic material.

[c35]            35.    The system of claim 29 wherein the first section of the coupling device includes a head and a shank portion, and wherein the first aperture includes a countersunk portion for receiving the head.

[c36]            36.    The system of claim 29 wherein the first section of the coupling device includes a head and a shank portion, and wherein the head has a radial extent greater than a radial extent of at least a portion of the first aperture.

[c37]            37.    The system of claim 29 wherein the second section of the coupling device includes a shank portion and a tail, the tail extending out of the second aperture, the tail having a radial extent greater than a radial extent of at least a portion of the second aperture.

[c38]            38.    The system of claim 29 wherein:

the first section of the coupling device includes a head and a shank portion, the head having a radial extent greater than a radial extent of at least a portion of the first aperture; and wherein the second section of the coupling device includes a shank portion and a tail, the tail extending out of the second aperture, the tail having a greater radial extent than a radial extent of at least a portion of the second aperture.

[c39] 39. The system of claim 29 wherein:  
the first section of the coupling device includes a head and a shank portion, the head having a radial extent greater than a radial extent of at least a portion of the first aperture; and wherein the second section of the coupling device includes a shank portion and a tail, the tail extending out of the second aperture, the tail having a greater radial extent than a radial extent of at least a portion of the second aperture; and wherein the first and second structures are clamped together by the head and the tail.

[c40] 40. The system of claim 29, further comprising a sealant proximate to the coupling device.

[c41] 41. The system of claim 29, further comprising a vehicle, and wherein the coupling device, the first structure, and the second structure are installed in the vehicle.

[c42] 42. A system of joined structures, comprising:  
a first structure having a first aperture, the first aperture having a first interior surface and a first minimum radial extent;



a second structure having a second aperture, the second aperture having a second interior surface and a second minimum radial extent at least approximately the same as the first minimum radial extent; and  
a coupling device having a first section extending through the first aperture and a second section extending through the second aperture, but not extending into the first aperture, the first section of the coupling device having at least one of a hardness, toughness, and density greater than that of the second section of the coupling device, and wherein a portion of the second section applies a first radial force to the second interior surface and the first section applies no radial force to the first interior surface or the first section applies a second lesser radial force to the first interior surface.

[c43] 43. The system of claim 42 wherein the portion of the second section has a greater radial extent than the first section.

[c44] 44. The system of claim 42 wherein the first structure includes a composite material and the second structure includes a metallic material.

[c45] 45. An aircraft, comprising:  
a first structure having a first aperture, the first aperture having a first interior surface;  
a second structure having a second aperture, the second aperture having a second interior surface, the first aperture having a minimum radial extent at least approximately the same as a minimum radial extent of the second aperture; and  
a coupling device having a first section extending through the first aperture and a second section extending through the second aperture, but not extending into the first aperture, the first section of the coupling device having at least one of a hardness, toughness, and density greater than that of the second section of the coupling device, and

wherein a portion of the second section has a greater radial extent than the first section.

[c46] 46. The system of claim 45 wherein the portion of the second section applies a first radial force to the second interior surface and the first section applies no radial force to the first interior surface or the first section applies a second lesser radial force to the first interior surface.

[c47] 47. An aircraft, comprising:

- a first structure including a composite material, the first structure having a first aperture, the first aperture having a first interior surface and a first minimum radial extent;
- a second structure including a metallic material, the second structure having a second aperture, the second aperture having a second interior surface and a second minimum radial extent at least approximately the same as the first minimum radial extent; and
- a coupling device having a first section extending through the first aperture and a second section extending through the second aperture, but not extending into the first aperture, the first section of the coupling device having at least one of a hardness, toughness, and density greater than that of the second section of the coupling device, wherein:
  - a portion of the second section has a greater radial extent than the first section so that the portion of the second section applies a first radial force to the second interior surface and the first section applies no radial force to the first interior surface or the first section applies a second lesser radial force to the first interior surface; and wherein
  - the first section of the coupling device includes a head and a shank portion, the head having a radial extent greater than a radial extent of at least a portion of the first aperture; and wherein

the second section of the coupling device includes a shank portion and a tail, the tail extending out of the second aperture, the tail having a greater radial extent than a radial extent of at least a portion of the second aperture.

[c48] 48. The system of claim 47, further comprising a sealant proximate to the coupling device.